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Neutron Sources for a Neutron Capture Therapy Facility

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Abstract

Recent advances in the development of boron pharmaceuticals have re-opened the possibility of using epithermal neutrons to treat brain tumors containing boron-10. This paper summarizes the approaches being used to generate the neutron sources and identifies specific areas where more research and development are needed.

Introduction

Despite the efforts of many researchers, the prognosis for a patient diagnosed with an inoperable advanced brain tumor (glioma) is dismal. The difficulty with using radiation therapy is that the tumor propagates by sending out microscopic clusters of cells close to the main body of the tumor. Even when the gross tumor is killed by radiation these clusters continue to grow. If a large margin is included around the gross tumor it is possible to destroy the clusters, but the process causes unacceptable damage to the healthy tissue in which the clusters are embedded. Hence, it is advantageous to sensitize the tumor cells to radiation without sensitizing the healthy cells. One way to sensitize the tumor is to introduce into the body a compound containing boron-10. Depending on the exact nature of the carrier, boron-10 will be absorbed by various parts of the body, including the tumor. However, healthy brain tissue will not absorb the compound because it is protected by the blood-brain barrier. When the brain is exposed to neutron radiation the large cross section for interactions between epithermal neutrons and boron-10 will result in a larger dose to tumor than healthy tissue.

In recent years the Department of Energy has been supporting research in the development of boron pharmaceuticals, and a number of drugs are ready or nearly ready for clinical trials. In addition, several reactors have been modified to provide neutrons for early clinical trials.[1] However, much work remains to be done in developing accelerator sources appropriate for hospital-based treatments.

"Low-energy" Accelerators

The present consensus is that the optimal neutron energy for boron neutron capture therapy (BNCT) is about 10 keV. Hence, one approach is to produce neutrons at as low an energy as possible so as to minimize moderating material. The threshold for producing neutrons by allowing protons to strike a lithium target is 1.8 MeV. For a beryllium target 2.2 MeV protons are required. The neutron yields become comparable at about 4 MeV. Proposals to generate neutrons using a lithium target have suggested using an electrostatic tandem cascade accelerator[2] or a radio frequency quadrupole linac (RFQ) as a proton source.[3] However, the practical problem of dissipating heat from a lithium target has not been solved and attention is now turning to the design of a ~4 MeV linear accelerator (linac) as a proton source.[4] This approach would require more moderation because the neutrons would be produced at higher energies, but design of a beryllium target presents fewer technical problems than a lithium target design. As of this writing none of the systems described here have actually been carried to the point of producing neutrons.

Spallation Sources

Another approach to neutron production uses 72 MeV protons from a cyclotron impinging on a heavy target such as tungsten. This method has the advantage of producing larger neutron fluxes but requires a great deal of moderation to lower the neutron energies to the keV range. Researchers at the Paul Scherrer Institute cyclotron have measured neutron fluxes produced this way.[5] They continue to make advances in target and moderator designs.

Fast Neutron Moderation

Clinical beams for fast neutron therapy are produced by allowing protons or deuterons with energies greater than 50 MeV to impinge on beryllium targets. Researchers at the U.S. facilities have been trying to determine whether the thermal/epithermal component of their beams is high enough to show a dose enhancement if boron-10 were present in the tumor. In particular, the facility at the University of Washington has reported that they have achieved a dose enhancement.[6] One advantage to using a moderated clinical fast neutron beam is that these facilities already have experience treating gliomas with fast neutrons and would view the addition of the boron drug as a slight modification to an existing therapy.

Conclusion

There is a great deal of interest in using BNCT for treating brain tumors. Boron drug synthesis is making reasonable progress. However, a number of technical challenges must be met before practical sources of epithermal neutrons will be available.

References

1 Rolf F. Barth, Albert H. Soloway, Ralph G. Fairchild, and Robert M. Brugger, "Boron Neutron Capture Therapy for Cancer", *Cancer*, Vol. 70, No. 12, 1992.

2 R.E. Shefer, R. E. Klinkowstein, J.C. Yanch and G.L.Brownell, "An Epithermal Neutron Source for BNCT Using a Tandem Cascade Accelerator," in *Progress in Neutron Capture Therapy for Cancer*, B.J. Allen, D.E. Moore and B.V. Harrington, eds., Plenum Press, New York, 1992, pp. 119-122.

3 M. A. Lone, A.M. Ross, J.S.Fraser, S.O. Schriber, S.A. Kushneriuk, and W.N.Selander, "Low Energy ^{7}Li(p,n)^{7}Be Neutron Source (Canutron)", Chalk River Laboratories, Internal Report AECL-7413, April, 1982.

4 C-K Chris Wang and Brian R.Moore, "On the Study of Energy Spectra and Angular Distributions of the Neutrons Emitted from a Beryllium Target Bombarded with 4-MeV Protons for Neutron Capture Therapy", *Proceedings of the Fifth International Symposium on Neutron Capture Therapy*, Columbus, Ohio, 1992.

5 J.F. Crawford, H. Reist, H.Conde, K. Elmgren, T. Roennqvist, E.Grusell, B.Nilsson, O. Pettersson, P. Stromberg and B. Larsson, "Neutrons for Capture Therapy Produced by 72 MeV Protons", in *Progress in Neutron Capture Therapy for Cancer*, B.J. Allen, D.E. Moore and B.V. Harrington, eds., Plenum Press, New York, 1992, pp. 129-132.

6 P. Wooton, R. Risler, J. Livesey, S. Brossard, G. Laramore, T. Griffin, "Boron Neutron Capture Enhancement of the Tumor Dose in Fast Neutron Therapy Beams", in *Progress in Neutron Capture Therapy for Cancer*, B.J. Allen, D.E. Moore and B.V. Harrington, eds., Plenum Press, New York, 1992, pp. 195-198.